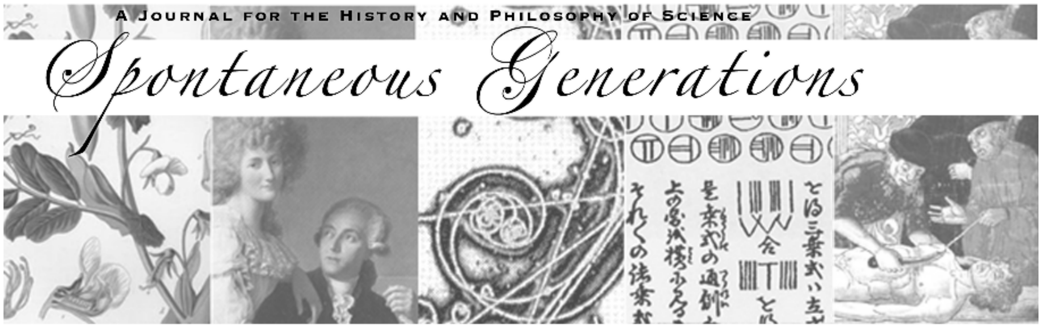

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Source: *Spontaneous Generations: A Journal for the History and Philosophy of Science*, Vol. 9, No. 1 (2018) 99-107.

Published by: The University of Toronto
DOI: *10.4245/sponge.v9i1.*

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Published online at *jps.library.utoronto.ca/index.php/SpontaneousGenerations*
ISSN 1913 0465

Founded in 2006, *Spontaneous Generations* is an online academic journal published by graduate students at the Institute for the History and Philosophy of Science and Technology, University of Toronto. There is no subscription or membership fee. *Spontaneous Generations* provides immediate open access to its content on the principle that making research freely available to the public supports a greater global exchange of knowledge.

Scientific Realism Again*

James Ladyman†

The debate about scientific realism has been pronounced dead many times only to come back to life in new form. The success of atomism in early-twentieth-century physics and chemistry was also a triumph for scientific realism, but quantum physics then revitalized empiricism and instrumentalism. The subsequent restoration of scientific realism in the work of Herbert Feigl and Hans Reichenbach was followed by Thomas Kuhn's ideas of paradigms and revolutions, which inspired many forms of antirealism about science. Many philosophers of science subsequently produced sophisticated defences of scientific realism that took account of the Duhem-Quine problem and the theory-ladenness of observation. Hilary Putnam coined the no-miracles argument, and renewed ideas of natural kinds. Scientific realism became the basis for naturalistic theories in epistemology, and physicalism in the philosophy of mind. By the time of Bas van Fraassen's seminal *The Scientific Image* (1980), scientific realism was not only dominant again in philosophy of science, but also foundational to the work of many other analytic philosophers (including in the growing community of metaphysicians, notably David Armstrong and David Lewis).

Constructive empiricism is a form of antirealism that does not deny scientific knowledge, progress, or the rationality of theory choice in general. For van Fraassen, the problem with scientific realism is not its commitment to the cumulativity and reliability of science, but rather that it adds metaphysics to empirical knowledge for no empirical gain. He argues that speculation about the unobservable world is of purely pragmatic value, to be embraced for its usefulness and dropped when it becomes idle. If theoretical science is regarded as modelling systems, rather than writing the book of the world, then believing in hidden causes and mechanisms beyond the phenomena, and regarding some empirical regularities and laws of nature as natural necessities of some kind, are not required. Van Fraassen's subsequent work made clear that he regards scientific realism as a rational position for those inclined to it, and seeks only to defend the reasonableness of agnosticism about unobservables. Strictly speaking, constructive empiricism is an axiology, not

* Received August 3, 2017. Accepted August 3, 2017.

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an epistemology, since it is first and foremost the view that the aim of science is to arrive at empirically adequate theories. Debate continues about this axiology (Churchland and Hooker 1985), about the meta-epistemological voluntarism within which it is framed (van Fraassen 1989; 2002), and about the theory of scientific representation developed by van Fraassen (2008).

The present paper concerns how scientific realism is formulated and defended. It is argued that van Fraassen is fundamentally right that scientific realism requires metaphysics in general, and modality in particular. This is because of several relationships that raise problems for the ontology of scientific realism, namely those between: scientific realism and common sense realism; past and current theories; the sciences of different scales; and the ontologies of the special sciences and fundamental physics. These problems are related. It is argued below that ontic structural realism, in the form of the real-patterns account of ontology, offers a unified solution to them all (or at least that it is required to do so, if it is to make good on the promise of naturalised metaphysics).[1] First there is more to note about the recent history of the realism debate.

Among the replies to van Fraassen's *The Scientific Image* in the collection *Images of Science* (1985), several themes recur:

(1) Realists object to any epistemological or ontological significance being given to the line between the observable and the unobservable.

(2) Realists argue that the fallible methods, in particular inference to the best explanation, used in everyday life to arrive at belief in observables that have not been observed, and to make inductive generalisations, are on a par with those used to arrive at beliefs in science involving unobservables.

(3) Realists think that the burden of proof is on the antirealist to show that there is a reason to doubt the first-order methods of science that recommend belief in entities such as black holes and electrons.

In respect of (3) above, note that while the no-miracles argument was dubbed the "ultimate" argument for scientific realism by Alan Musgrave (1988), scientific realists such as Alexander Bird (2018) regard it as unnecessary, given the reliability of first-order inference to the best explanation in science. Whether or not this is granted, there is no scientific realism debate at all if everything is left to first-order questions that scientists debate about whether, for example, a particular particle or species exists. The idea that there is a wholesale versus a retail way of thinking about scientific realism (Magnus and Callender 2004) is unhelpful, because the issue is essentially a global or second-order one, not a local or first-order one, in the first place. If one is content to let debates within the sciences decide

[1] This paper builds on, and defends, the view of Ladyman and Ross (2007), and Ladyman and Ross (2013). See also Ladyman (2017).

what unobservable entities exist, and to take their apparent ontological commitments at face value, then one is a scientific realist.

A serious problem for scientific realism that is not addressed by (1) and (2) above, and that provides the anti-realist with a response to (3), is pressed in Larry Laudan's work (1977, 126; 1984), which argues from the history of theory change in science, and makes an empirical challenge to scientific realism that echoes Henri Poincaré (1952, 160), Ernst Mach (1911, 17), and Hilary Putnam (1978, 25). It is this argument, namely the "pessimistic meta-induction," that motivates John Worrall's structural realism (1989). In its crude form it says that since most, if not all, past theories have turned out to be false, we should expect our current theories to turn out to be false. However, Laudan's ultimate argument from theory change against scientific realism is not really an induction of any kind, but a *reductio*. No attempt at producing a large inductive base needs to be made; rather, one or two cases are argued to be counterexamples to the realist thesis that novel predictive success can only be explained by successful reference of key theoretical terms (see, for example, Ladyman 2002 and Psillos 1999).

There is much discussion about theories of reference in the literature; however, whether or not some particular theoretical term refers is a red herring for realists attempting to account for many cases of theory change. The term "ether" is now regarded as not referring by most commentators on the scientific realism debate, but there is no particular reason why it was abandoned by science, as it could have been retained to describe the electromagnetic field. After all, the term "atom" has been retained to refer to divisible entities that are not purely or even largely mechanical in their interactions (see Stein 1989). Arguably the ether has much more in common with the field than atomic physics does with the atoms of atomism. Regardless of which terms refer, the question is whether it is plausible to say that the metaphysics and ontology of science is true or approximately true. The problem is that there are many cases in which successive theories use the same terms, such as "space," "time," "gravity," "mass," and "particle," but the claims made about what there is in the world, and especially about the metaphysics of those theories, are very different.

Nonetheless, as Heinz Post (1971) observed, the well-confirmed laws of past theories are limiting cases of the laws of successor theories (which is his General Correspondence Principle). Hence, it is not just the empirical content or phenomenological laws of past theories that are retained, but also the law-like relations they posit. The laws take mathematical form and there are special cases, such as that of Fresnel's equations, where the very same equations are reinterpreted in terms of different entities. However, structural realism does not require that all mathematical (or any other kind of) structure be retained on theory change. If it did, it would be refuted by the fact that the mathematics of Newton is different from that of Einstein. The point is that while the ontological status of the relevant entities may be very different in the different theories, the relationship between the structures of the theories is readily represented, and indeed in many cases it can be studied in depth by investigation of the relevant mathematical structures. Ladyman and Ross (2007) argue that mathematical representation is ineliminable in much of science, and take this to be key to the formulation and defence of ontic structural realism. Note, however, that this does not mean that this kind of structural realism only applies to mathematicized theories. Even though there is no such thing as phlogiston, the tables of affinity and antipathy of phlogistic chemistry express real patterns that we now express in terms of reducing and oxidizing power (see Ladyman 2011).

In many cases the strongly empirically successful theories of the past are also the theories presently used in the relevant domain. For example, Newtonian mechanics, ray and wave optics, classical electrodynamics, and classical statistical mechanics are all still used, although of course in every case there is a superior fundamental theory. The ontology of such theories remains "effective," in the sense that the entities it posits are part of empirically successful descriptions and models. For example, in the BCS theory of superconductivity, the material in question is treated as a lattice of sites at which there may or may not be pairs of electrons, and interactions between the latter are mediated by "phonons," which are treated as if they were genuine particles within the model. Phonons correspond to vibrations in the system, and they are not taken as fundamental, but they are real enough for scientific practice in the relevant domain. Similarly, in particle physics there are effective theories, with their effective ontologies, that only apply at certain emergent scales of description. (See Ladyman [2015] for more on the idea that particles are effective individuals in physics.) Indeed, the supposedly abandoned ontology of classical physics, in the form of point particles obeying Newtonian dynamics, is still a major object of study in current physics.

Entities that are now regarded as emergent are also often the entities of past theories, and are always merely effective with respect to more fundamental descriptions. For example, solids and liquids, as well as magnetic and electric fields, are part of the effective ontology of condensed matter physics, even though none of these things is part of the ontology of quantum field theory. In this sense, much of physics is like special science. The special sciences in general deal with a plethora of emergent entities, properties, and processes. Scientific realism as such has no account of the relationship between ontologies, nor of the relationship between causation and law, at different levels, and in different sciences, and this is problematic for its formulation and defence.

Eddington's famous two tables example poses the problem of reconciling the ontologies of atomic physics and everyday material objects. Arguments for realism based on causation, intervention, and explanatory power in theories dealing with emergent phenomena only establish effective ontology at best. Many philosophers, scientific realists among them, argue for the elimination of all such entities in favour of the fundamental physical stuff. It is often argued that such emergent entities lack any genuine causal powers, these all necessarily residing at the fundamental physical level, and so are merely devices to be adopted for pragmatic reasons. Hence, the antirealist can argue that the scientific realist must grant that taking a pragmatic, but non-realist attitude to reference to theoretical entities is reasonable, because many scientific realists take that attitude themselves to large parts of science. (This argument is also made by Paul Teller [forthcoming].)

More generally, scientific realism can hardly be defended as an extension of everyday ontology and reasoning to the unobservable as in (1) and (2) above, if everyday objects are supposed to be eliminated in favour of fundamental physical entities. Furthermore, scientific realism cannot be defended by appeal to the first-order practices of science as in (3) above, if the latter can be taken as delivering ontological commitments that are ultimately to be repudiated as mere epistemologically useful fictions. It is ironic that scientific realism taken to extremes, in the form of the view that only the fundamental physical stuff is real, is now the major form of instrumentalism about much of the ontology of the special sciences.

There is a conflict between fundamentalism and realism about the ontologies of the special sciences. However, it is not necessary to advocate disunity or a patchwork view to reject fundamentalism and reductionism, and to maintain realism at the level of the special sciences. Ladyman and Ross (2007) defend the latter's "rainforest realism" by conjoining it with ontic structural realism in the philosophy of physics, adopting scientific realism about effective ontology, and modifying the theory of real patterns to provide a criterion of existence. A real pattern is, very roughly, something that makes for a simplified description relative to some background ontology. (The real-patterns account thus unifies entity realism with structural realism.) For example, a wave on the beach is a real pattern to a surfer, or a lifeguard, because it is taken as the basis for prediction and explanation. Waves are very ephemeral real patterns, like currents and tides, but rocks and sandbanks are more durable. In physics, quasi-particles like phonons are taken to exist when their half-life is effectively infinite relative to the scale of the interactions that are being studied. In general, Ladyman and Ross argue that ontology is scale-relative, in the sense that different energy levels and regimes, as well as different length and time scales, feature different emergent structures of causation and law. Real patterns are entities of whatever ontological category that feature (non-redundantly) in projectible regularities. (David Wallace [2015] also argues for the real-patterns account of effective emergent entities such as quasi-particles.) The above account could be interpreted as being of the pragmatics of an ultimately epistemological kind of emergence, but if there is not, or might not be, a fundamental level of reality, nor ultimate individuals of which everything else is made, then all real patterns are on a par.

The real-patterns account also explains why we do not abandon old ontologies in much of scientific practice, because the strongly empirically successful theories of the past had many laws that were correct in their domains of applicability. Since everyday objects and their properties are projectible in various ways, the real-patterns account is also applicable to common-sense realism, and so solves the problem of Eddington's two tables. The table is a real pattern at macroscopic scales, but at the microscopic scale it dissolves into molecules that are bound together by electromagnetic potentials. There is a rough correspondence between the everyday object and the bound state of the particles that compose it, but there is not even token identity between them, since they have different modal properties—the table would exist even if some of the relevant particles did not but the bound state would be different—and because they have different persistence conditions—the table could have a leg replaced but the bound state would not survive such an operation.

The problems of vagueness of composition and identity over time as well as generation and corruption all apply to both special science objects and everyday ones. The real-patterns account of ontology offers a unified solution for both problems in all cases. Composition is often dynamical, especially in science, but the time scale of the interactions of the parts is very short compared to the time scale characteristic of the whole (see Ladyman 2017). Generation and corruption are not events at the level of the parts, but real patterns can indeed be created and destroyed by changes in the behaviour of other real patterns, and they can also persist over long time scales relative to the scale of the interactions of their parts.

In any case, the scientific realist must give some account of the relationship between ontology at different scales and in different sciences. Eliminativism about emergent ontology makes scientific realism a form of antirealism about most, if not all, actual science, and undercuts the arguments for realism (as in [1] and [2] above). Reductionism is arguably not plausible and is certainly not popular among scientific realists. Pluralism is the option many scientific realists take. For example, Teller (forthcoming) thinks in terms of a multitude of simplified models of a much more complex reality, each of which gives a partially but not completely correct picture. Such models, though not completely correct, capture aspects of the modal structure of the world. For him, and many others, there is no one right form of description. Pluralists are right that there are multiple models, often at different scales and in different regimes. However, this notwithstanding, there is often one theory choice that is right—oxygen over phlogiston being a good example. Moreover, as Ladyman and Ross (2007) argue, pluralism does not do justice to the unity of science, nor does it take account of the special status of physics. The need for theories to be compatible where they overlap is a methodologically productive driver of scientific advancement suggestive of a non-pluralist metaphysics.

The real-patterns account thus permits an understanding of ontology as scale-relative, that is, compatible both with the unity of science, and with a very weak form of physicalism (though not with most forms of physicalism). Modality is the key to the real-patterns account of ontology, which harmonizes entity realism and ontic structural realism, because featuring in projectible models and/or statements is taken to be the criterion of reality. The real-patterns account also explains why focusing on issues of reference across theory change is a red herring for the realist, because reference can always be secured to some extent whenever there are real patterns that are carried over as approximations.

The issue remains as to whether effective ontology deserves to be called ontology at all, however, as it is arguably just an epistemological gloss in lieu of a full description. Weak forms of emergence allow that emergent entities are epistemologically and semantically irreducible, but take it that strong emergence, and full ontological status, would be ruled out by any claim that genuine causal power resides only at the fundamental level. However, if the latter claim is false then that modal structure at all scales could be considered real. Explicating how that is possible requires further elaboration, but given that it presents the most promising way to resolve many of the issues facing scientific realism, I suggest that the present focus of the scientific realism debate should be on providing such an account of the relationship between the modal structures found in scientific theories at different ontological scales.

There are different ways this might be done. For both French and Ladyman ontic structural realism has been from the outset about modal structure (see French and Ladyman 2003). However, French is an eliminativist about all ontology except the structures of physics, while the real-patterns account is ecumenical. On the other hand, alternatives to structuralism involving theories of dispositions, essences, and powers have been developed in conjunction with the defence of scientific realism by Alexander Bird, Anjan Chakravartty, and Brian Ellis. At the very least, this all seems to lend credence to van Fraassen's claim that scientific realism is essentially a metaphysical position of some kind. While Barry Loewer, David Papineau, and Stathis Psillos are Humeans and deny that scientific realism requires any notion of natural necessity, Berenstain and Ladyman (2012) argue that the arguments for scientific realism are undercut without it. This metaphysical issue is taken as the fundamental one for the realism debate by van Fraassen, and he is right: metaphysics in general, and modal metaphysics in particular, are the crux of scientific realism.

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